International Journal of Civil, Structural,
Environmental and Infrastructure Engineering
Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 5, Issue 2, Apr 2015, 63-68


TRANS STELLAR
• Journal Publications • Research Consultancy

# GEAR STUDY AND RIGID PAVEMENT METHODOLOGIES AND ANALYSIS FOR BOEING 747

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## ABSTRACT

The aim of this paper is about the study done for the selection of aircraft on the basis of gears i.e. to enable the aircraft to manoeuvre on ground and the methods applied for finding out stresses in slabs. For the purpose wheels are required over which the aircraft may run and carry the entire weight of the aircraft. The major portion of total loads carried by two main gears which are provided in the fuels age or in the wings near the junction of fuels age and wings. Therefore, the third wheel, which is provided near the tail or nose, carries very small portion (about 10%) of the total load. Large modern day aircraft utilize either bicycle or tricycle landing gears. In the case of tricycle landing gears, the main gear load can be of single,dual or twin tandem type.

Most rigid-airfield pavement design techniques are based at least in part upon theoretical stresses in elastic slabs, modified by field experience and appropriate safety factors. The safety factors are applied depend to a large extent upon the type of feature like stress, the slabs etc. The magnitude of distress of rigid airfield pavement depends upon repetition of load, gear configuration, gross load, tire pressures and type of features(i.e taxiways,runway).

According to theoretical analysis, the magnitude of stresses in pavements depends also upon the modulus of subgrade reaction, modulus of elasticity of the concrete and poissons ratio of the concrete.

**KEYWORDS:** Rigid Pavement, Gears, Portland Cement Association (PCA), Corps Engineer's Method, Westergaard's Method, Boeing 747

## INTRODUCTION

According to the International Civil Aviation Organization (ICAO) a **runway** is a "defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft". Runways may be a man-made surface (often asphalt, concrete, or a mixture of both) or a natural surface (grass, dirt, gravel, ice, or salt).

Runway usually oriented in the direction of prevailing winds. The head wind, i. e the direction of wind opposite to the direction of landing and take-off, provides greater lift on the wings of the aircraft when it is taking off.

Runway dimensions are very important factors in the runway planning in concern with aircraft performance and cost of airport layout.

## GEAR SELECTION

Aircraft is selected on the basis of gears. To enable the aircraft to manoeuvre on ground wheels are required over which the aircraft may run and carry the entire weight of the aircraft.

Wheel loads: Types of airplane and truck wheel arrangements can be divided into several basic categories, including single and dual wheels, single and tandem axles, and nose wheel, tricycle, and bicycle landing gears.

Large modern day aircraft utilize either bicycle or tricycle landing gears. In the case of tricycle landing gears, the main gear load can be of single, dual, or twin-tandem type.

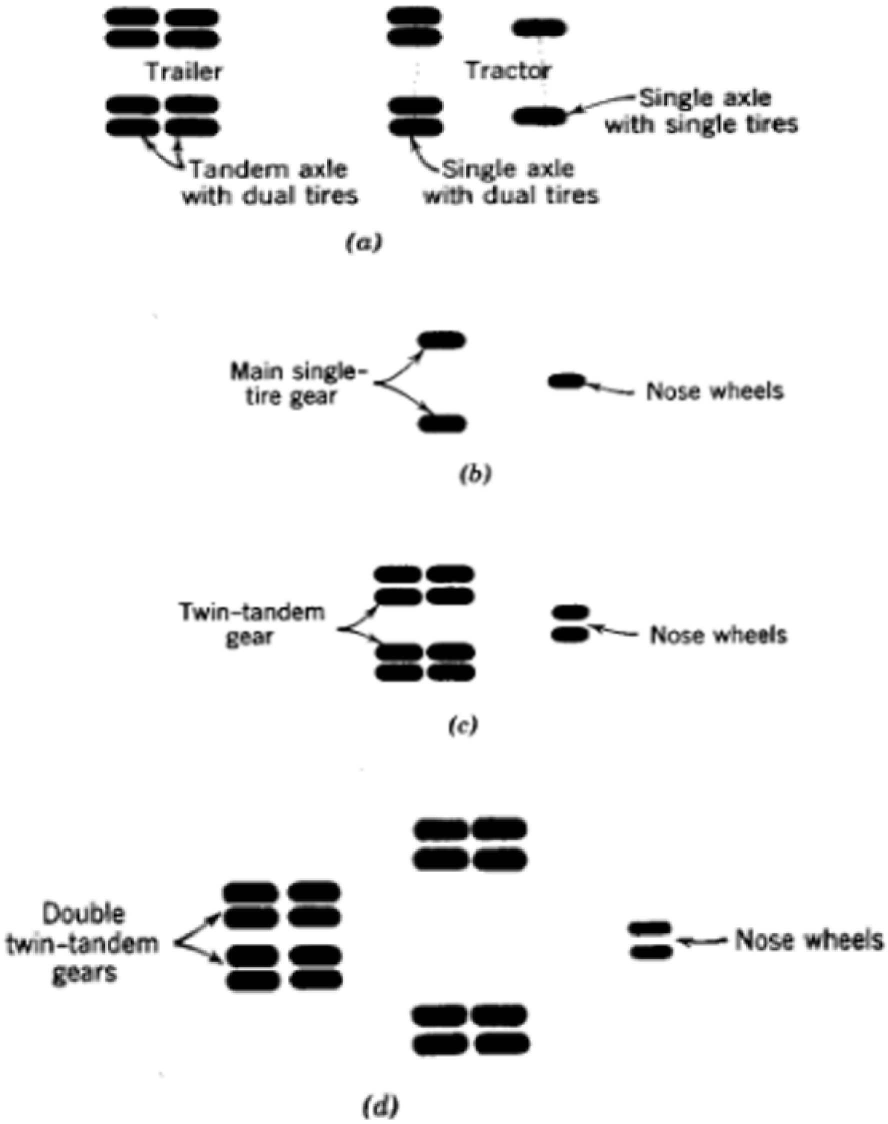


**Figure 1: Plan View of Several Basic Types of Wheel Configuration**

## DESIGN METHODOLOGIES OF RIGID PAVEMENT

Most rigid–airfield pavement design techniques are based on theoretical stresses in elastic slabs,modified by field experience and appropriate safety factors.

The design methodologies are:

- **Portland Cement Association Method**
- **Corps Engineer's Method**
- **Westergaard's Method**

**Portland Cement Association Method**

The Portland Cement Association has published design charts that are based on the interior loading case(reference 2). The charts are also based upon the assumption that the subgrade as dense liquid. Interior loading conditions are based upon the assumption that interior joints have adequate load transfer, thus making the stress analysis for interior loading conditions are valid. These design charts are available for several specific aircraft. The modulus of elasticity of the concrete is assumed to be 2812.27832 kg/cm$^2$, and Poisson's ratio for the concrete is 0.15.

The left hand vertical scale i.e the Y- axis is the modulus of rupture determined from beam breaking tests. The appropriate factor of safety must be applied to this value before entering the chart. The charts can also be used to determine the stress existing in a pavement of known characteristics under various wheel loads by working the chart backwards.

Factor of safety as recommended by Packard are as follows:

Aprons, taxiways, hard standings, runway ends, hangar floors-1.7 to 2.0

Runways (central portion) high speed exit taxiways 1.4 to 1.7

**Corps of Engineers Method**

Corps of Engineers Method is based upon edge loading case. These are based upon the design curves (reference 2).Thickness of pavement is determined in a manner identical to that described above. The modulus of rupture, however, which is used on the left-hand Y-axis, is the value determined by field test. The factor of safety is included in the chart.

The design curves are on the basis of light, medium, and heavy load pavements. The curves give thickness values for various traffic areas A, B and C.

Type A traffic areas are subjected to the greatest concentration of maximum loaded aircraft.

Type B traffic areas are those subjected to the normal distribution of the maximum loaded aircraft.

Type C are those areas having a reduced loading of the aircraft or where the speed of the aircraft results is less than maximum stress in the pavement.

**Westergaard Method**

Cement concrete pavement represent the group of rigid pavements. Here the load carrying capacity is mainly due to the rigidity and high modulus of elasticity of the slab action. H. M. Westergaard is considered the pioneer in providing the rational treatment to the problem of rigid pavement analysis.

Westergaard considered the rigid pavement slab as thin elastic plate resting on soil subgrade, which is assumed as a dense liquid. Here it is assumed that the upward reaction is proportional to the deflection, i.e., $p=K\Delta$, where the constant

K is defined as modulus of subgrade reaction.The unit of K is kg/cm² per cm deflection i.e., kg/cm³.

**Relative Stiffness of Slab to Subgrade**

A certain degree of resistance to slab deflection is offered by the subgrade. This is dependent upon the stiffness or pressure-deformation properties of the subgrade material. The tendency of the slab to deflect is dependent upon its properties of flexural strength.

The resultant deflection of the slab which is also the deformation of subgrade is a direct measure of the magnitude of subgrade pressure. The pressure deformation characteristics of rigid pavement is thus a function of relative stiffness of slab to that of subgrade.

Westergaard defined this term as the Radius of relative stiffness

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4}$$

Here l=radius of relative stiffness, cm

E = modulus of elasticity of cement concrete kg/cm²

μ= Poisson's ratio for concrete = 0.15

h = slab thickness, cm

K = subgrade modulus or modulus of subgrade reaction, kg/cm³

**Westergaard's Stress Equation for Wheel Loads**

The cement concrete slab is assumed to be a homogenous, thin elastic plate with subgrade reaction being vertical and proportional to deflection.

The commonly used equations for theoretical computation of wheel load stresses have been given by Westergaard. He considered three typical regions of the cement concrete pavement slab for the analysis of stresses,as the interior ,edge and the corner regions. The critical stresses Si, Se and Sc at the typical locations i.e interior edge and corner are given as

**Interior Loading:** Si=$\left(\frac{0.316P}{h^2}\right)\left[4\log_{10}\left(\frac{l}{b}\right)+1.069\right.$

**Edge Loading:** Se $=\left(\frac{0.572P}{h^2}\right)\times\left[4\log_{10}\left(\frac{l}{b}\right)+0.359\right]$

**Corner Loading: Sc**=$\left(\frac{3P}{h^2}\right)\times\left[1-\left(\frac{a\sqrt{2}}{l}\right)\right]$

**Here:** Si, Se, Sc=maximum stress at interior, edge and corner loading, respectively, kg/cm²

h=slab thickness in cm, P=wheel load in kg, a=radius of wheel load distribution in cm

l=radius of relative stiffness, cm

b=radius of resisting section, cm

If the slab thickness h is to found for the allowable values of maximum stresses Si,Se and Sc trials are required for

assumed values of h. Bradbury suggested a simplified procedure by expressing all euations in the general form

$$S=\frac{P}{h^2}\times Q$$

## METHODS APPLIED ONBOEING 747

**Table 1**

| S. No | Method | Input | Output | Remark | Modulus of Rupture= Stress/Depth |
|---|---|---|---|---|---|
| 1 | Portland Cement Association | gear load=362874kg | | soil is dense liquid,interior loading case considered | 1.43626 |
| | | k=8.4kg/cm³ | thickness=26.924cm | | |
| | | stress=38.67kg/cm² | | | |
| 2 | Corps Engineer's method | gear load=362874kg | thickness=40.132cm | soil is dense liquid,edge loading case considered | 0.9635 |
| | | k=8.4kg/cm³ | | | |
| | | stress=38.67kg/cm² | | | |
| 3 | Westergaard's method | gear load=362874kg | | soil is dense liquid;inetrior,edge and corner loading are assumed and expressed in general form | 1.43316 |
| | | k=8.4kg/cm³ | stress=57.3704kg/cm² | | |
| | | thickness=40.0304cm | | | |

## SUMMARY AND CONCLUSIONS

It can be observed from the above discussionsthat after studying the stress developed for the aircraft Boeing 747, it can be concluded that the Westergaard's method is more suitable for rigid pavement design. As the modulus of rupture ratio is going on higher side, this is considered for the optimized design. There is optimization of the runway depth along the runway panel by Westergaard's method as the stress is increased.

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